J. Agromet Indonesia 21 (1) : 12 – 20, 2007

PREDICTION OF DAILY RAINFALL CHARACTERISTICS FROM MONTHLY CLIMATE INDICES

(Prediksi Karakteristik Curah Hujan Harian dari Parameter Iklim Bulanan)

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ABSTRAK

Informasi karakteristik curah hujan seperti deret hari kering, deret hari basah, curah hujan maksimum dan lainnya diperlukan untuk perencanaan pertanian. Kejadian deret hari kering panjang pada periode tanam, terutama selama fase pertumbuhan yang sensitif terhadap kekeringan harus dihindarkan. Informasi ini akan membantu petani dalam merencanakan waktu dan pola tanamnya. Jika informasi karakterisitik curah hujan harian dapat diprediksi sebelum musim tanam, maka perencanaan tanam dapat dikembangkan. Anomali suhu muka laut di Pasifik , perbedaan tekanan udara Darwin dan Jakarta , dan perbedaan tekanan udara Tahiti dan Darwin adalah indikator iklim yang berhubungan dengan keragaman curah hujan Indonesia. Berbagai model GCM telah dikembangkan untuk prediksi berbagai indikator dan hasil pediksinya dapat diakses dari berbagai situs. Prediksi indikator ini untuk satu tahun ke depan diberikan dalam bentuk bulanan. Penelitian ini menguraikan pengembangan model pembangkit data iklim yang menggunakan curah hujan bulanan sebagai input untuk membangkitkan data curah hujan harian. Hubungan antara anomali curah hujan dan dan parameter iklim juga diteliti, sehingga anomali curah hujan pada musim berikutnya dapat dapat diprediksi dengan menggunakan parameter tersebut. Hasil prediksi curah hujan dibangkitkan untuk mendapatkan data iklim harian. Karakteristik hujan harian seperti deret hari kering dan deret hari basah dibangkitkan dengan Excel spreadsheet menggunakan simulasi Monte Carlo. Hasil analisis menunjukkan bahwa karakterisrik data hujan hasil bangkitan tidak berbeda dengan data observasi. Selanjutnya penggunaan prediksi hujan bulanan yang digunakan sebagai input pembangkitan data diharapkan dapat menghasilkan data harian yang sama dengan data observasi untuk musim berikutnya.

Kata Kunci : Pembangkit data iklim, anomali suhu muka laut, tekanan udara, simulasi Monte Carlo

ABSTRACT

Information on rainfall characteristics such as dry-spell, wet-spell, maximum rainfall and some others are required for agricultural planning. The occurrence of long dry-spell in growing season, in particular during a growing stage sensitive to drought, should be avoided. This information will assist farmer to arrange their planting time and cropping pattern. If information on daily rainfall characteristics could be predicted before planting season is started, better planting arrangement could be developed. Pacific sea surface temperature anomaly, Darwin and Jakarta air pressure difference, Tahiti and Darwin air pressure difference, are climate indices that have been found to be related to Indonesian rainfall variation. Many GCM models have been developed for the prediction of these indices and the predicted indices can be accessed easily from many web-sites. Prediction of the indices for one-year period ahead is given in monthly basis. This study described the development of a weather generator model that used monthly rainfall as inputs for generating

Penyerahan naskah : 12 Februari 2007
Diterima untuk diterbitkan : 8 April 2007

daily rainfall data. Relationship between monthly rainfall anomaly and the climate indices is developed. Thus, the likely monthly rainfall anomaly for coming season can be estimated from the indices. This predicted rainfall anomaly is then used to tune the weather generator model for the creation of statistically-based daily weather data for specific sites. The characteristics of daily rainfall such as dry spell, wet spell are generated using Excel spreadsheet that has been furnished with Monte Carlo simulation capability. Results of analysis showed that statistical characteristics of generated rainfall data are similar to the characteristic of observed data. Therefore, the use of predicted monthly rainfall data for coming season as input for the weather data generator model is expected to yield likely daily rainfall data for the coming season.

Keywords: weather data generator, sea surface temperature anomaly, air pressure, *Monte Carlo* simulation.

INTRODUCTION

Many facts show that when pacific sea surface temperature (SST) deviates from normal, most of region in Indonesia experiences deviant rainfall. For instance during El-Nino episodes, pacific sea surface temperature above normal, most of Indonesia regions receive much less rainfall (Nicholls, 1989). In addition, the end of dry-season normally October was clearly delayed by at least a month for Java and Bali (Malingreau, 1987) but no delay in the onset of the dry season. The opposite pattern is observed during La-Niña years. There is also some evidence suggesting that the beginning of the following rainy season after an El-Niño is likely to be wetter than normal.

As pacific SST is closely related to Indonesian rainfall, many studies have been carried out to evaluate the relationship between pacific SST anomaly and rainfall anomaly in Indonesia (Las et al., 1999). Most of studies were carried out using monthly data. It was found that SST anomaly was significantly related to monthly rainfall anomaly. Using the relationship equations, likely anomaly monthly rainfall in the coming season could also be predicted from predicted anomaly pacific SST. However, for agricultural planning information on characteristics of daily rainfall will be more useful than that of monthly rainfall. Therefore, a technique to forecast likely daily rainfall characteristics from monthly rainfall data is required. This paper discusses the development of a weather data generator model that used monthly rainfall as inputs for generating daily rainfall data. The use of the weather data generator model for predicting likely daily rainfall characteristics from predicted monthly rainfall anomaly was also discussed.

METHOD OF ANALYSIS

The development of the weather data generator model was using daily data from 61 stations spread over Indonesia. Analysis consists of several steps. First, to estimate the probability of having rain on day i given that rain occurred on day $i\text{-}1$ ($p_{11}(i)$) and rain not occurred on day $i\text{-}1$ ($p_{01}(i)$). The $p_{j1}(i)$ were estimated from the proportion of years for which rain occurred on day i, considering only those years for which rain occurred ($j=1$) or not occurred ($j=0$) on day ($i\text{-}1$). Second is to pool p_{j1}(i) estimates from daily basis to monthly basis. Third is to develop equations for estimating pooled $p_{j1}(i)$ from monthly rainfall. Fourth is to develop equations to fit seasonal pattern of the $p_{j1}(i)$. Fifth is to determine statistical distribution for depth of daily rainfall. Sixth is to develop equations for estimating parameters of the distribution from altitude based on inspection of the seasonal pattern in the above pooled $p_{j1}(i)$, it was suggested that the logistic transform:

$$g_{j1}(i)=ln[p_{j1}(i)/\{1\text{-}p_{j1}(i)\}]$$

could be fitted using Fourier Regression:

$$g_{j1}(i)=a_0+\sum_{k=1}^{n}[b_k\,sin(ki')+c_k\,cos(ki')]$$

where $k=1,\ 2,\ ....,\ n$ is number of harmonic, and $i'=2\pi i/12$. Value of i is estimated using the following equation (Epstein, 1991):

$$i = (T\text{-}0.5)+(m\text{-}0.5)/D$$

where D is number of days in month T and m is sequence number of day in month T. The fitted lines developed from the pooled $g_{j1}(i)$ were then compared with those developed from non-pooled $g_{j1}(i)$. Fitted lines for non-pooled $g_{j1}(i)$ were also developed using Fourier regression but variable i' in the equation was calculated as follows :

$$i' = 2\pi i/365 \text{ and } i = 1, 2, \ldots, 365$$

Statistical distribution used to fit rainfall data was Gamma. Many studies found that this distribution fit well with rainfall data (Ison *et al.*, 1971; Stern and Coe, 1984; Waggoner, 1989; Wilks, 1991)

Seventh is to develop simple linear regression equations that relate anomaly of monthly rainfall with anomaly of climate indices. The analysis was performed using weighted regression analysis. In this study the term 'climate indices' are used to define several indices, *i.e.* anomaly of pacific sea surface temperature at Nino1+2, Nino3, Nino3.4, Nino4, SOI and anomaly of air pressure difference between Darwin and Jakarta. The last index was developed as this air pressure different has been found to be closely related with rainfall variation in Java (Boerema, 1941).

The likely monthly rainfall anomaly for coming season was estimated from predicted climate indices accessed from NOAA web-sites. This predicted rainfall anomaly was used to estimate the likely monthly rainfall in the coming season by taking the sum of long term mean of rainfall for given month and the monthly rainfall anomaly for that given month. The predicted monthly rainfall is then used to tune the parameters of weather generator model for the creation of statistically-based daily rainfall data using equations developed in step three of the analysis.

The characteristics of daily rainfall such as dry spell, wet spell, maximum length of spells etc. are generated using Excel spreadsheet that has been furnished with *Monte Carlo* simulation capability called as 'Crystal Ball'.

RESULTS AND DISCUSSIONS

Results of analysis showed that the fitting lines resulted from pooled and non-pooled $g_{j1}(i)$ was almost overlap (Fig 1). Further analysis also showed that the pooled $g_{j1}(i)$ are significantly related to mean monthly rainfall (Fig. 2). These two suggests that in the absence of daily rainfall data, the $p_{j1}(i)$ can be estimated from monthly rainfall depth. Statistical distribution that fit to rainfall data was Gamma distribution.

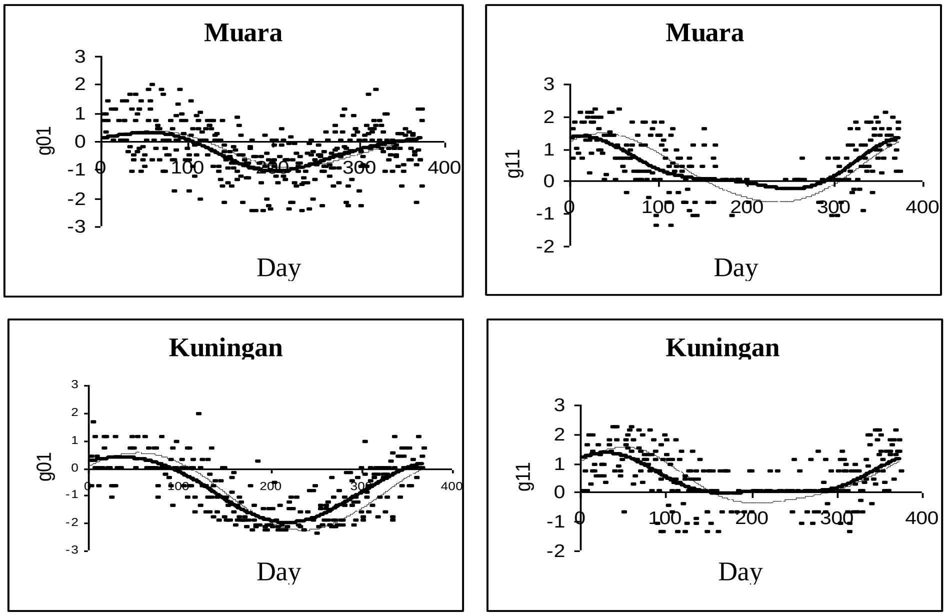

Figure 1. Examples of fitting lines for pooled (—— : monthly basis) and non-pooled g_{j1} (▬: daily basis) at two stations.

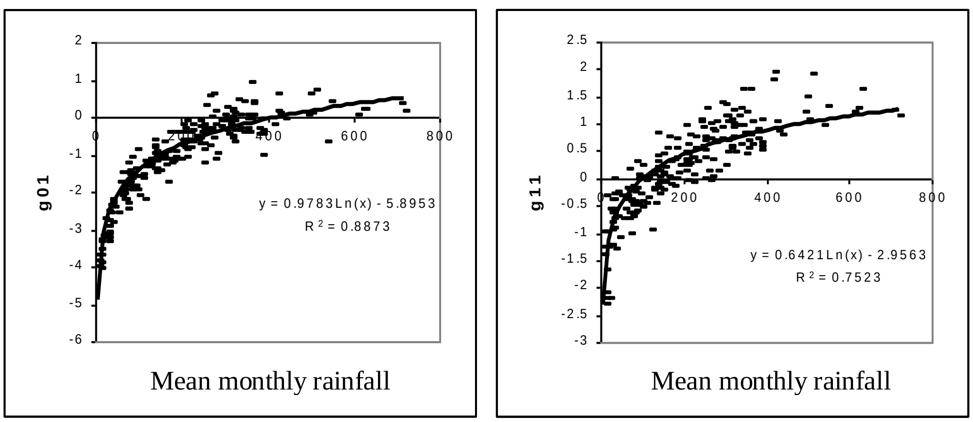

Figure 2. Relationship between mean monthly rainfall and $g_{j1}(i)$. Dots represents observed data from 61 stations.

Parameters of the distribution, shape (α) and scale (β) parameters, are significantly related to altitude of the stations. It was suggested that the relationships were linear (Fig. 3).

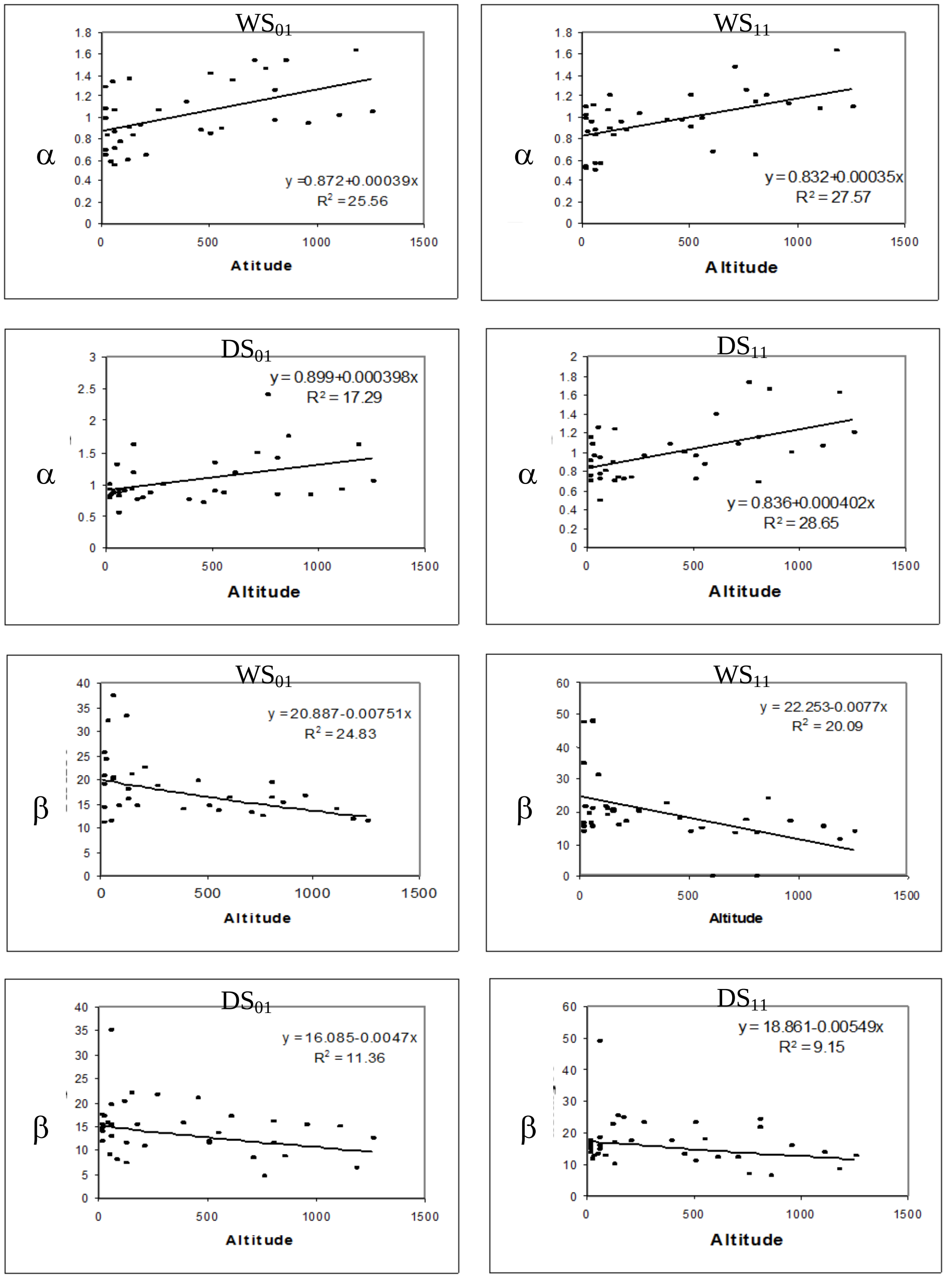

Figure 3. Relationship between parameters of Gamma, α and β, with altitude for condition 01 and 11 at dry season (DS) and wet season (WS)

Values of α increase with altitude while those of β are opposite. From correlation analysis between climate indices (anomaly of pacific SSTat Nino1+2, Nino 3, Nino 3.4 and Nino 4, Tahiti-Darwin air pressure difference and Darwin-Jakarta air pressure difference) and anomaly of monthly rainfall (AMR) of 30 rainfall stations at Flores, it was found that in most of stations anomaly pacific sea surface temperature at Nino 3.4 (ASST3.4) have stronger relationships with the anomaly of monthly rainfall than other climate indices. Furthermore, it was shown that the correlation is stronger in dry season than in wet season. Number of stations that have significant correlation with the ASST3.4 is also more in dry season than in wet season. In dry season about 15 stations have significant correlation with ASST-3.4 while in wet season it was only eight stations. Correlation between ASST3.4 and AMR varied from station to other stations, i.e from 0.2 to 0.5 with average of about 0.35. Results of the analysis showed that the statistical characteristics of the generated daily rainfall data are similar to those of observed data (Figure 4).

Different from Flores-NTT, at Subang, West-Java climate index that has stronger relationship with anomaly of monthly rainfall was Darwin-Jakarta air pressure difference. The air pressure difference accounts for about 30% of variation of rainfall anomaly in most of stations at Subang district, while other climate indices only account for about less than 15% in all stations. Using the above results, the generation of daily rainfall data from monthly rainfall data could be carried out.

The process of data generation is the following:

1. Calculate mean monthly rainfall,
2. Estimate monthly rainfall anomaly using predicted climate indices,
3. Predict the likely monthly rainfall for the coming season by summing the mean monthly rainfall with the estimated monthly rainfall anomaly,
4. Estimates $g_{jk}(i)$ from the mean monthly rainfall or from predicted monthly rainfall,
5. Estimates coefficients of Fourier regression equations for $g_{j1}(i)$ using Epstein method,
6. Estimates parameters of Gamma distribution from altitude,
7. Simulate daily rainfall occurrence by comparing the estimate $p_{j1}(i)$ with sample randomly taken from uniform distribution, $U_{(0,1)}$. If $U_{(0,1)} > p_{j1}(i)$, rain does not occur, and if $U_{(0,1)} < p_{j1}(i)$, rain occurs,
8. Simulate daily rainfall depth using Gamma distribution.

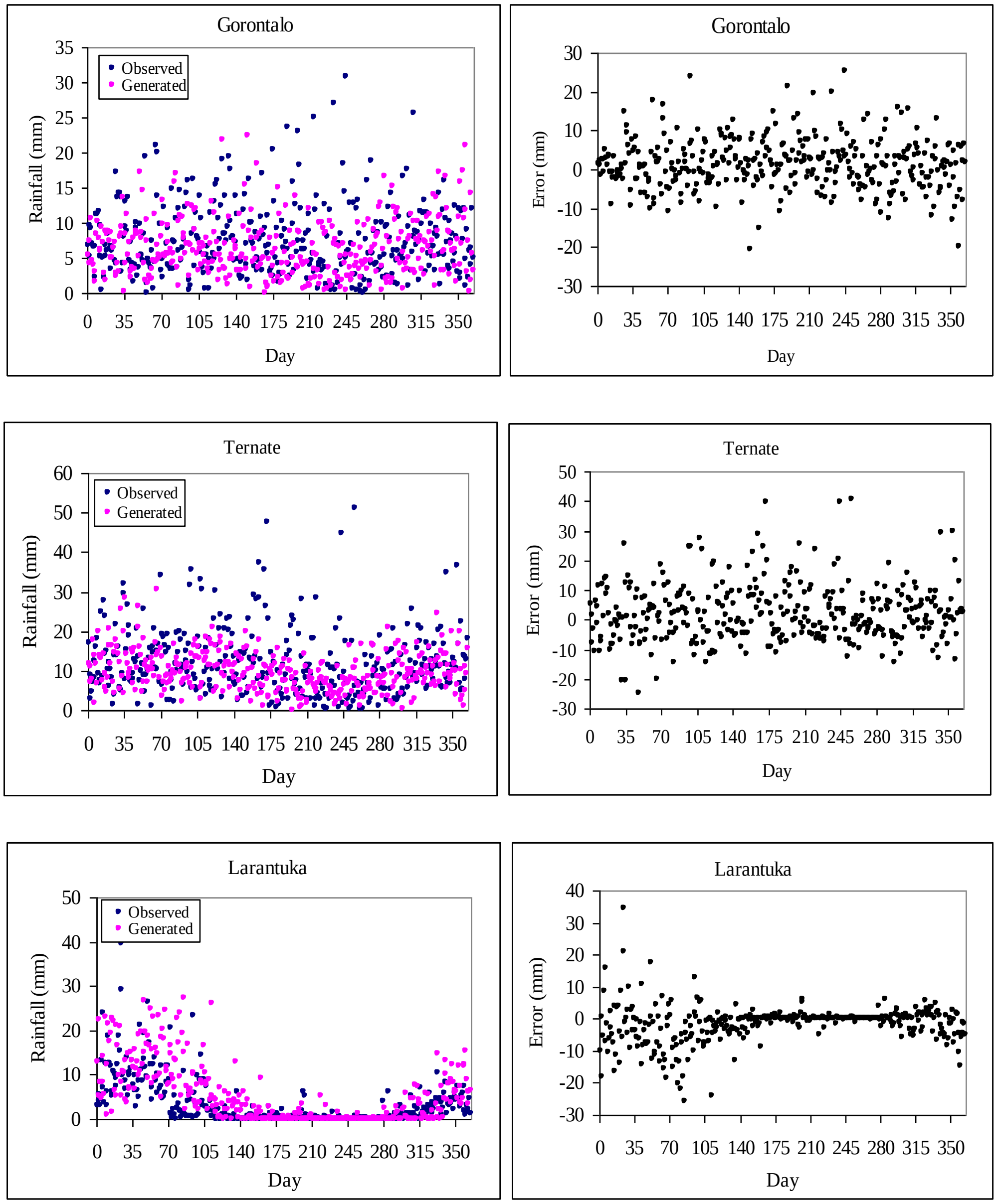

Figure 4. Comparison between observed and generated rainfall data

The use of this weather data generator has been demonstrated by Guntoro *et al.* (1999) in evaluating the optimum planting time for soybean at Bajawa, Flores. They found that variation of yield of soybean for a given planting time was determined by maximum length of dry spell occurring during vegetative period and number of rainy days during generative period. Yield of soybean will decrease if length of dry spell during vegetative period is longer and number of rainy days during generative period is lower. Therefore, the optimum planting time should be a time of planting so that the probability of having long dry spell during the vegetative period is minimum and probability of having high number of rainy days is maximum.

Crystal Ball, a spreadsheet that has been furnished with Monte Carlo simulation capability could be used to determine probability of occurrence of these daily rainfall characteristics. As an example, soybean planting in March 1 may expose to dry spell with a minimum length of 6 days with probability of about 20% (Fig. 5). Furthermore, if yield of soybean is expressed as a function of these daily rainfall characteristics, distribution of yield for that given planting time can also be determined.

As $p_{j1(i)}$ can be estimated from mean monthly rainfall (Fig. 2) and parameter of Gamma distribution for rainfall depth from altitude (Fig. 3), the likely change in monthly rainfall in the coming season due to the occurrence of ENSO phenomena can be translated into daily rainfall characteristics that may occur in the season. This information can be used to evaluate whether normal recommended planting time is still suitable to be used in that season.

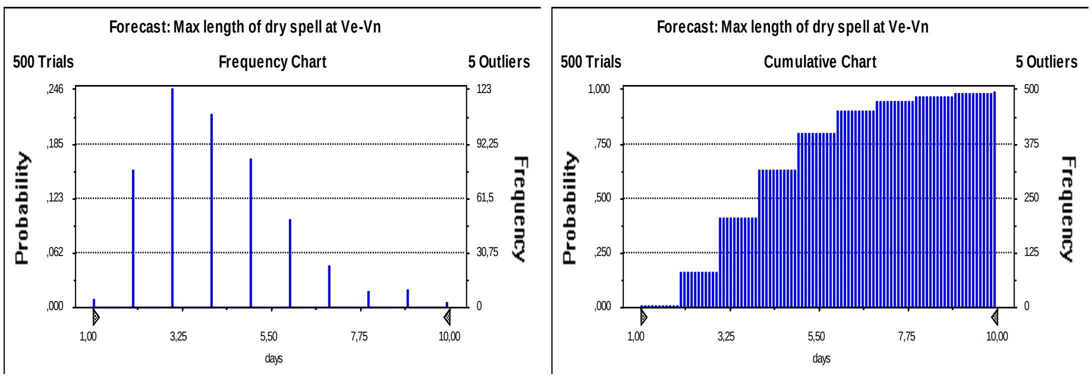

Figure 5. Probability and cumulative probability of having maximum length of dry spell at vegetative period of soybean planted in March 1 at Bajawa.

CONCLUSION

Monthly rainfall data can be used to generate daily rainfall that has similar statistical characteristics with observed data. If information on predicted climate indices for coming season is available, likely monthly rainfall anomaly in the coming season can be estimated and thus its impact on daily rainfall characteristics can be assessed. This information can be used to evaluate recommended planting time in that coming season and to assess the variation of crop yield.

ACKNOWLEDGEMENTS

This work is part of RUT-IV report. National Research Council that provided financial support for this work is acknowledged.

REFERENCES

Boerema, J. 1941. Rainfall types in Indonesia. Verh. 34, Indonesia.

Epstein, E.S. 1991. On obtaining daily climatological values from monthly means. *Journal of Climate* 4:365-368.

Guntoro, W., Rizaldi Boer, Irsal Las, Khairil A. Notodiputro, dan Ahmad Bey. 1999. Penggunaan '*Stochastic Spreadsheet'* untuk Penentuan Waktu Tanam Optimum Kedelai di Boawae, Flores-NTT. Accepted for Publication at *Jurnal Agromet*.

Ison, N.T., Feyerherm, A.M., and Bark, L.D. 1971. Wet period precipitation and the gamma distribution. *Journal Applied of Meteorology* 10:658-665.

Malingreau, J.P. 1987. The 1982-83 drought in Indonesia: Assessment and monitoring. In M. Blantz, R. Katz and M. Krenz. Climate crisis: The societal impacts associated with the 1982-83 worldwide climate anomalies. UNEP.

Nicholls, N. 1989. ENSO, drought and flooding rain in South-East Asia. In H. Brookfield and Y. Byron (eds). South-east Asia's Environmental Future. United Nations University Press. Tokyo.

Stern, R.D., and Coe, R.T. 1984. A model fitting of daily rainfall data. *Journal Royal Statistics Society* 147:l-34.

Waggoner, P.E. 1989. Anticipating the frequency distribution of precipitation if climate change alters its mean. *Agricultural and Forest Meteorology* 47:321-337.

Wilks, D.S. 1991. Conditioning stochastic daily precipitation models on the total monthly precipitation. *Water Resource Research* 25:1429-1439.